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- L2: (712) (audio adj (ti
- L3: (19095) (bit adj shi
- L4: (32) 1 and 3
- L5: (9) 2 and 3
- L6: (32) 4 or 5
- L7: (1) 10/766895
- L8: (254) 369/59.21
- L9: (613) G11B020/20
- L10: (1510) 386/96
- L11: (40763) H04N005/91
- L12: (18) 369/59.21
- L13: (134) 386/96

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3	BRS	L3	19095	(bit adj shift)	US-P GPUB	2007/03/2 0 10:31			
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METHOD AND APPARATUS FOR CONTROLLING LASER POWER

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to a laser power control apparatus and a laser power control method.

[0003] 2. Description of the Related Art

[0004] In recent years, in the fields of an auxiliary storage device for a computer, a consumer video cassette recorder and the like, a demand for a rewritable optical disk device has been on the rise. Generally, a semiconductor laser light source has been employed for formation of a recording mark on an optical disk. There is a necessity for a semiconductor laser to emit a light pulse for formation of a good recording mark. In order to form a recording mark, for example, a semiconductor laser is, as shown in **FIG. 6**, intensity-modulated between a peak power and a bottom power to perform multipulse light emission. For formation of a recording space, a semiconductor laser emits light continuously for a predetermined time at a bias power. In order to secure a stable recording performance, it is necessary to control the laser powers precisely. A power characteristic of a semiconductor laser, however, is greatly affected by an ambient temperature or the like. Accordingly, even if powers are set once prior to recording to supply given driving currents, the powers have no chance to be kept at the given values, resulting in fluctuations in the powers accompanying a rise in temperature of a semiconductor laser body or its peripheral equipment.

[0005] As a means to avoid fluctuations in the powers, it is useful to calibrate the powers in regular intervals. In an optical disk format having a sector structure, for example, there is provided a laser control region in a sector for calibrating a laser power one time at each sector. In this case, each time a light spot passes over a laser control region, a power is calibrated in the laser control region, thereby enabling fluctuations in the powers to be avoided.

[0006] A description will be given of a power calibration method in a laser control region in the conventional art using **FIG. 9** below.

[0007] (a) When a light spot arrives at a laser control region, a given current Iop1 is supplied to a laser. A laser power P1 at this time is detected as a laser power detection voltage Vm1 by a laser power detecting means including a light receiving element and a current-voltage conversion circuit.

[0008] (b) Then, a given current Iop2 is supplied to the laser. A laser power P2 at this time is detected as a detection voltage Vm2 by the laser power detecting means. The laser power detection voltages Vm1 and Vm2 are converted by an arithmetic circuit to the respective laser powers P1 and P2.

[0009] With such a procedure applied, as shown in **FIG. 10**, it is possible to obtain a relationship of a laser power with a laser driving current in calibration (hereinafter the relationship is referred to "a laser I-L characteristic"). Therefore, by driving a laser with a driving current corresponding to a desired power in the recording region, the laser can be driven with a desired power (this scheme is hereinafter referred to as "continuous (DC) light emission scheme).

[0010] A problem remains in the continuous light emission scheme, however. In a case where a frequency characteristic of a light receiving element is low, a laser has to be driven for a long time at given values in order to settle laser power detection voltages Vm1 and Vm2. In a case where a laser is continuously emitted at the power P2 of the order of a recording peak power as compared with the power P1 of the order of an erase power, a recording film on an optical disk is illuminated with a continuous high power, leading to degradation of the recording film formed by vapor deposition. In each data rewriting, illumination with the continuous high power to the recording film was performed and repeated for a long time, which would result in inconveniences that not only is the laser control region degraded, but the degradation of a recording film is also spread into even a data recording region. Since light emission is repeated in each of laser control regions continuously at a high power for a long time, a lifetime of a semiconductor laser has a high possibility to be shortened.

[0011] As a method to avoid the problem as described above, there has been disclosed a method as taught in, for example, Japanese Laid-open Patent Publication No. 2000-244054. A description will be given of a power calibration method in a laser control region in Japanese Laid-open Patent Publication No. 2000-244054 with reference to **FIGS. 11 and 12**.

[0012] **FIG. 11** is a block diagram of a configuration of a laser control apparatus in Japanese Laid-open Patent Publication No. 2000-244054. **FIG. 12** is an operation sequence diagram of the apparatus.

[0013] (a) When a light spot arrives at a laser control region, a driving current Iop1 is supplied to a laser by a laser driving circuit **140** to perform a continuous (DC) light emission at the bias power **P1**.

[0014] (b) A light emission power at this time is detected by a laser power detecting means **100**. The laser power detecting means **100** is constituted of a light receiving element **101**, a current-voltage conversion circuit **102**, a peak detecting circuit **116**, a bottom detecting circuit **115** and a multiplexer **117**.

[0015] (c) The multiplexer **117** is configured so as to select a peak detection voltage y outputted from a peak detecting circuit **116**, a bottom detection voltage z outputted from a bottom detecting circuit **115** and a through output x of the current-voltage conversion circuit **102** according to control signals v and w from the outside.

[0016] (d) In continuous (DC) light emission at an erase power P1, the through output x is selected by the multiplex **117** to output Vm1 as a laser power detection voltage.

[0017] (e) In succession, driving currents Iop2 and Iop3 are supplied while being switched therebetween to the laser to thereby perform pulse light emission between a recording peal power P2 and a bottom power P3.

[0018] (f) A light emission power at this time is detected by the laser power detecting means **100**. In

this situation, there is outputted a switching waveform between Vm2 and Vm3 as a through output x from the current-voltage conversion circuit **102**. From the peak detecting circuit **116**, there is outputted a peak detection output y in which the peak level Vm2 of the through output x is held for a given period. From the bottom detecting circuit **115**, there is outputted a bottom detection output z in which the bottom level Vm3 of the through output x is held for a given period. The peak detection output y and the bottom detection output z are selected by the multiplexer **117** in a proper manner to output Vm2 or Vm3 as a laser power detection voltage.

[0019] The laser power detection voltages Vm1, Vm2 and Vm3 produced in such ways are converted to digital values by the AD conversion circuit **121** to further convert the digital values to laser powers P1, P2 and P3 with an arithmetic processor **125**. Thus, an I-L characteristic of the laser can be produced by the arithmetic processor **125**.

[0020] With such a construction adopted, the same output as a detection output obtainable by continuously driving a semiconductor laser itself for a long time can be produced from the peak detecting circuit **116** since the peak level Vm2 is held for a given period. In this scheme, since the semiconductor laser emits light pulses, so a laser power illuminated to a recording film is reduced as compared with a continuous (DC) light emission scheme, damage caused on a recording film decreases, thereby enabling reduction in lifetime of a semiconductor laser to be alleviated.

[0021] Even in the above scheme having the construction, there have been remained problems. In a case where a higher speed recording is tried, or in a case where a higher precision DC characteristic is requested by a laser power detecting unit and a frequency characteristic of a current-voltage conversion circuit can not be sufficiently secured, an output of the current-voltage conversion circuit does not reach Vm2 or Vm3 to thereby reduce a power detecting precision. Furthermore, in a case where a width of a light pulse is increased for the purpose to cause an output of the current-voltage conversion circuit to reach Vm2 and Vm3, there occur inconveniences such as damage caused on a recording film, reduction in lifetime of a semiconductor laser and the like in a similar way to that in the continuous (DC) light emission scheme.

SUMMARY OF THE INVENTION

[0022] It is an object of the invention to provide a semiconductor laser power control method capable of correctly controlling a laser power at a desired level even in a case where a frequency characteristic of a laser power detecting means is not sufficiently secured.

[0023] In accordance with one aspect of the present invention, there is a method for controlling a laser power used in recording on an optical disk, the method including:

[0024] causing the laser to emit a test light emission pattern including a multipulse light emission interval in which a pulse current intensity-modulated between a peak value current and a bottom value current in formation of a recording mark onto the optical disk is supplied to thereby cause the laser to emit light pulses; and an at-bottom value continuous light emission interval in which the bottom value current is continuously supplied for a predetermined time to thereby cause the laser to emit light continuously;

[0025] receiving the test light emission pattern of the laser to convert the pattern to an electric signal and to thereby obtain a light detection signal;

[0026] calculating a detection value of a multipulse average value from the average value of the light detection signal in the multipulse light emission interval, and calculating a bottom detection value from the light detection signal in the at-bottom value continuous light emission interval to thereby obtain a light emission power characteristic of the laser on the supplied current based on the detection value of the multipulse average value and the bottom detection value; and

[0027] controlling the current supplied to the laser based on the light emission power characteristic on the current supplied to the laser.

[0028] In the step of causing the laser to emit the test light emission pattern, the test light emission pattern used preferably further includes an at-bias value continuous light emission interval in which a bias value current in formation of a recording space is supplied continuously for a predetermined time to thereby cause the laser to emit light continuously. In this case, in the step of obtaining the light emission power characteristic of the laser, a bias detection value is further calculated based on the light detection signal in the at-bias value continuous light emission interval to thereby obtain the light emission power characteristic of the laser on the supplied current based on the bias detection value, the detection value of a multipulse average value and the bottom detection value.

[0029] In the step of causing the laser to emit the test light emission pattern, the test light emission pattern used preferably further includes a spontaneous light emission interval in which a current less than a threshold current at which the laser emits light is supplied to the laser to cause spontaneous light emission. In this case, in the step of obtaining the light emission power characteristic of the laser, an offset is detected based on a detection value of the light detection signal in the spontaneous light emission interval.

[0030] In the step of causing the laser to emit the test light emission pattern, the test light emission pattern used preferably further includes a light-off interval in which a supplied current is set substantially to zero to turn the laser off. In this case, in the step of obtaining the light emission power characteristic of the laser, an offset is detected based on a detection value of the light detection signal in the light-off interval.

[0031] In a laser power control method related to the invention, a time width Tmp of the multipulse light emission interval preferably satisfies the following relation with respect to a time width Tmax of the longest recording mark of data in a recording region of the optical disk:

$$T_{max} < T_{mp}.$$

[0032] The time width Tmp of the multipulse light emission interval preferably satisfies the following relation with

respect to a wobble cycle T_{wbl} on a recording track of the optical disk:

$$Tmp<T_{wbl}/2.$$

[0033] A time width Tb of the at-bottom value continuous light emission interval preferably satisfies the following relation with respect to a time width Tmax of the longest recording mark of data in a recording region of the optical disk:

$$Tmax<Tb.$$

[0034] The time width Tb of the at-bottom value continuous light emission interval preferably satisfies the following relation with respect to a wobble cycle T_{wbl} on a recording track of the optical disk:

$$Tb<T_{wbl}.$$

[0035] A time width Tmp of the multipulse light emission interval and a time width Tb of the at-bottom value continuous light emission interval preferably satisfy the following relation with respect to a time width $T_{apcarea}$ during which scanning is performed over a laser power control region provided on the optical disk for controlling a power of the laser:

$$Tmp+Tb<T_{apcarea}.$$

[0036] A time width Te of the at-bias value continuous light emission interval preferably satisfies the following relation with respect to a time width Tmax of the longest recording mark of data in a recording region of the optical disk:

$$Tmax<Te.$$

[0037] A time width Te of the at-bias value continuous light emission interval preferably satisfies the following relation with respect to a wobble cycle T_{wbl} on a recording track of the optical disk:

$$Te<T_{wbl}/2.$$

[0038] A time width T0 of the spontaneous light emission interval preferably satisfies the following relation with respect to a time width Tmax of the longest recording mark of data in a recording area of the optical disk:

$$Tmax<T0.$$

[0039] The time width T0 of the spontaneous light emission interval preferably satisfies the following relation with respect to a wobble cycle T_{wbl} on a recording track of the optical disk:

$$T0<T_{wbl}.$$

[0040] A time width T0 of the light-off interval preferably satisfies the following relation with respect to a time width Tmax of the longest recording mark of data in a recording area of the optical disk:

$$Tmax<T0.$$

[0041] The time width T0 of the light-off interval preferably satisfies the following relation with respect to a wobble cycle T_{wbl} on a recording track of the optical disk:

$$T0<T_{wbl}.$$

[0042] In a laser power control method related to the invention, in the spontaneous light emission interval, a current I_{led} supplied to the laser preferably satisfies the following relation with respect to a threshold current Ith of the laser:

$$Ith/4 \leq I_{led}<Ith.$$

[0043] In the spontaneous light emission interval, a current I_{led} supplied to the laser more preferably satisfies the following relation with respect to a threshold current Ith of the laser:

$$Ith/4 \leq I_{led} \leq Ith*3/4.$$

[0044] In the spontaneous light emission interval, a current I_{led} supplied to the laser further more preferably satisfies the following relation substantially with respect to a threshold current Ith of the laser:

$$I_{led}=Ith/2.$$

[0045] An apparatus for controlling a power of a laser used in recording on an optical disk including:

[0046] a formatter having a test light emission pattern including a multipulse light emission interval in which a pulse current intensity-modulated between a peak value current and a bottom value current in formation of a recording mark onto the optical disk is supplied to the laser to thereby cause the laser to emit light pulses; and an at-bottom value continuous light emission interval in which the bottom value current is continuously supplied to the laser for a predetermined time to thereby cause the laser to emit light continuously;

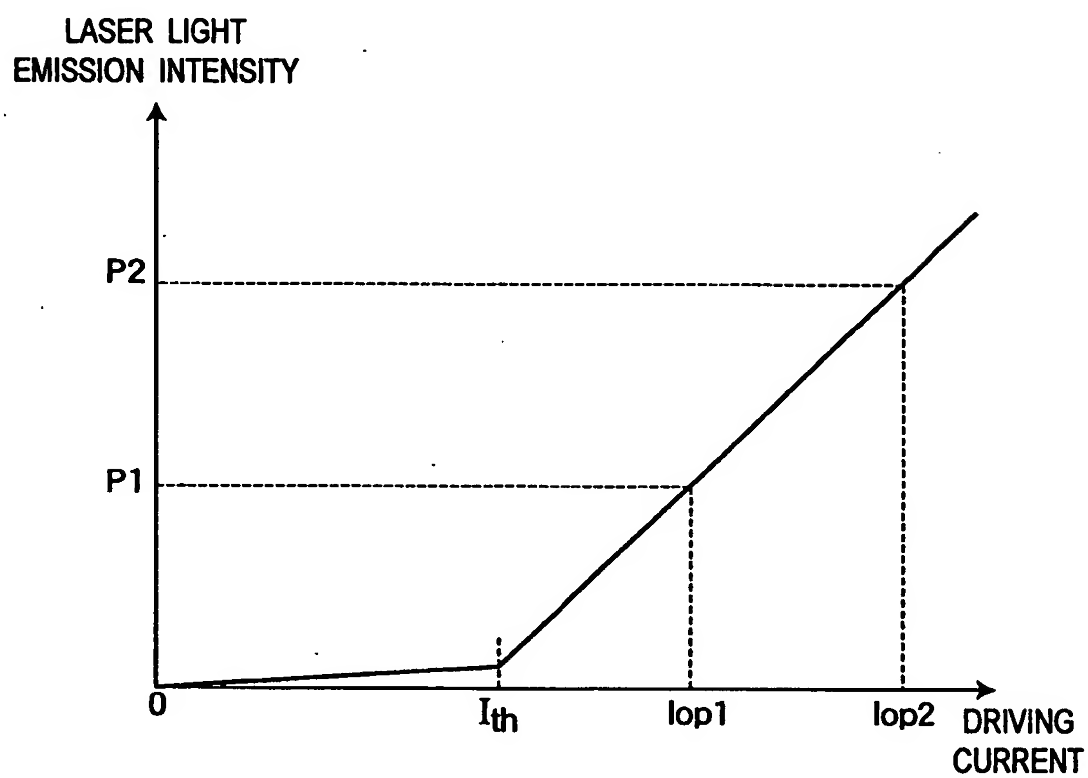
[0047] a laser driving unit supplying a current to the laser based on the test light emission pattern transmitted from the formatter to cause test light emission;

[0048] a laser power detecting unit receiving the test light emission pattern of the laser to convert the pattern to an electric signal and to thereby obtain a light detection signal; and

[0049] an arithmetic unit which calculates a detection value of a multipulse average value from the average value of the light detection signal in the multipulse light emission interval, and which calculates a bottom detection value from the light detection signal in the at-bottom value continuous light emission interval to obtain a light emission power characteristic of the laser on a supplied current based on the detection value of a multipulse average value and the bottom detection value, and to control the current supplied to the laser based on the light emission power characteristic.

[0050] In a laser power control apparatus related to the invention, the test light emission pattern preferably further includes an at-bias value continuous light emission interval in which a bias value current in formation of a recording space is supplied to the laser continuously for a predetermined time to thereby cause the laser to emit light continuously. In this case, in the arithmetic unit, a bias detection value is further calculated based on the light detection signal in the at-bias value continuous light emission interval to thereby obtain the light emission power characteristic of the laser on the supplied current based on the bias detection value, the detection value of the multipulse average value and the bottom detection value.

Fig.10


LASER LIGHT
EMISSION INTENSITY
P2
P1
0
Ith
Iop1
Iop2
DRIVING
CURRENT